16th World Conference on Earthquake, 16WCEE 2017

Santiago Chile, January 9th to 13th 2017

Paper 3254

The Application of U-Shaped Metallic Yielding Dampers in Retrofitting of Steel Frames

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Abstract

The reduction of structural response under dynamic loads has cut serious attentions in recent decades. Steel yielding dampers are used as a devise to control the structural response under wind and quake loads. In this paper, three steel moment frame in 3, 5 and 8stories are analyzing in a nonlinear time history under four different motions. With respect to failure of elements, U-shaped steel yielding dampers have been added by knee braces of the structures. In this paper, in addition to defining nonlinearity of damper, nonlinear specification of beams and columns by assigning plastic hinges on this elements have been considered. The results show transferring nonlinearity of elements to the damper and the failure of the frame will reduce. Dampers will develop frame behavior and reduced lateral displacement and story shear. Also they increase energy dissipation of frame.

Keywords: Plastic hinges, U-shape damper, Energy dissipation, failure of frame;

1. Introduction

One of the problems that most major cities around the world are grappling with is the damage caused by natural disasters such as earthquakes, floods, fires and so on. Iran's geographical scope in terms of the probability of occurrence of these events, particularly earthquakes, is the most vulnerable parts of the planet that saw a lot of human and financial losses resulting from the occurrence of the events in it annually. One of the most important issues in the field of structural engineering, reducing the damage caused by this natural disaster. Earthquake is one of the events that took place in spite of much research in this field is still not possible to predict the exact time and place of its occurrence[1]. That's why one of the main challenges of structural and earthquake engineers is to find a tool to deal with the devastation caused by the earthquake[2].

One approach to dealing with seismic vibrations is stiffening and strengthening the structure to withstand lateral loads on structures within the permitted deformation. Structural damping is the main factor in attracting and energy dissipation in this method, material inherent damping and inelastic behavior of materials are two factor of this method[3].

Another approach is to use the method for transferred energy losses or reduction to the structure caused by external forces, to reduce the seismic forces and seismic response. Structural behavior control mainly is divided into three categories: passive control, active control and semi-active control[4].

The discussed damper is a metallic yielding U-shaped damper that is made up of curved steel and flexural yielding parts that absorb energy. To this end, three steel moment frame with three, five and eight stories will be considered. The damper with inverted V brace is added to the frame, and then integral non-linear time history analysis is done.

In this study, to take a closer look at the behavior of the damper and the frame during different earthquakes, non-linear time history analysis using SAP 2000 software is done. Another important point, is assigning the non-linear behavior of structural members such as beams and columns plastic hinges, to analyze trends, in addition to the damper components which resist against external forces by non-linear behavior and are dissipating portion of the input energy, Frame members also participate in the process and thus, the behavior of the frame will be closer to the behavior of the damper.

2. Modeling

All of the steel moment frames have been considered to be two dimensional steel moment frame with intermediate ductility. Four frames with three, five, eight and twelve stories have been used for this purpose; each having three spans with 5m length and load span length was 5m. Each story has 3 meter height and all connection have been rigid.

Sections used in the model are as follows:
Column: BOX
Beam: IPE
Brace: Inverted V shape made by BOX

Yielding strength for steel, f_y=2400kg/cm^2,Young's modulus, 2e6 kg/cm^2 and Poisson's ratio, 0.3 have been considered. Dead load and Live load of load span was purposed to be, 700kg/m^2 ,200kg/m^2 respectively.
Standard No.2800 Iranian design code have been used for initial seismic analysis and design was based on the assumption that the summary is as follows:

2. Dampers Properties

In this study, the U-shaped dampers which is now the subject of two U-shaped each damper is formed in front of each other. Depending on the need, in different frames, damper with different characteristics are used. Each damper is defined as units of U (for example U1, U2 and etc.). U- shaped pieces of damper U1 are composed of two curved pieces and every piece of metal plate has the cross-sectional dimensions 10x100 mm and radius of curvature 50 mm was built. In various dampers, damper specification is fixed. Stiffness and yielding force had linear relation with width of damper's piece.

3. Structure Properties

Frame with three spans with three, five and eight stories chosen were linear static analysis and design, then, to consider damper nonlinear behavior during earthquakes, frames were integral non-linear time history analysis.To do so, the four accelerograms was used in the two levels of accelerograms with maximum ground acceleration of 0.4 times the acceleration due to gravity and two levels of accelerograms with maximum ground acceleration of 0.6 times the acceleration due to gravity. Frames are designed for the earthquake level 0.4ginitially and damper for checking the behavior of dampers in very severe earthquakes, frames were reinforced and modified frames, as described here, analyzed and dampers behavior were evaluated.

4. Members Properties

Beams and columns sections are describe in table 1 to table 8. Connecting the damper inside the frame, inverted V braces with box cross section can be used. For example, five and eight-story frame is equipped with a damper are shown in figure 1 and 2.

Table1. Member's properties in 3 story frame with 3 spans

Damper0.6g	Damper 0.4g	Side Column	Central Column	Side Beam	Central Beam	story
1U	0.5U	Box20x20x1	Box20x20x1	IPE 330	IPE 330	1
1U	0.5U	Box20x20x1	Box20x20x1	IPE 330	IPE 330	2
1U	0.5U	Box20x20x1	Box20x20x1	IPE 330	IPE 330	3

Table2. Member's properties in 5 story frame with 3 spans

Damper0.6g	Damper 0.4g	Side Column	Central Column	Side Beam	Central Beam	story
1U	1U	Box25x25x2	Box25x25x2	IPE 360	IPE 360	1
1U	1U	Box25x25x2	Box25x25x2	IPE 360	IPE 360	2
1U	1U	Box25x25x2	Box25x25x2	IPE 360	IPE 360	3
1U	1U	Box25x25x2	Box25x25x2	IPE 330	IPE 330	4
1U	1U	Box25x25x2	Box25x25x2	IPE 330	IPE 330	5

Table3. Member's properties in 10 story frame with 3 spans

Damper0.6g	Damper 0.4g	Side Column	Central Column	Side Beam	Central Beam	story
1U	1U	Box30x30x2	Box30x30x2	IPE 450	IPE 450	1
1U	1U	Box30x30x2	Box30x30x2	IPE 450	IPE 450	2
1U	1U	Box30x30x2	Box30x30x2	IPE 450	IPE 450	3
1U	1U	Box30x30x2	Box30x30x2	IPE 400	IPE 400	4
1U	1U	Box30x30x2	Box30x30x2	IPE 400	IPE 400	5
1U	1U	Box30x30x2	Box30x30x2	IPE 330	IPE 330	6
1U	1U	Box30x30x2	Box30x30x2	IPE 330	IPE 330	7
1U	1U	Box30x30x2	Box30x30x2	IPE 330	IPE 330	8
1U	1U	Box30x30x2	Box30x30x2	IPE 330	IPE 330	9
1U	1U	Box30x30x2	Box30x30x2	IPE 330	IPE 330	10

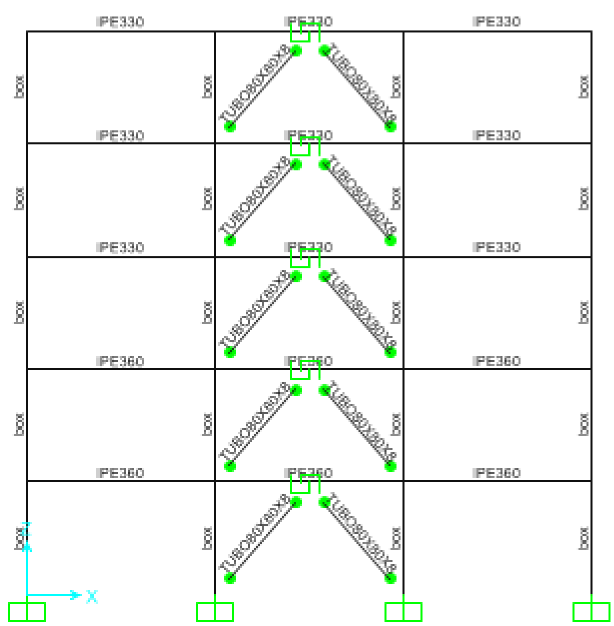

Figure1. 5 story frame with damper

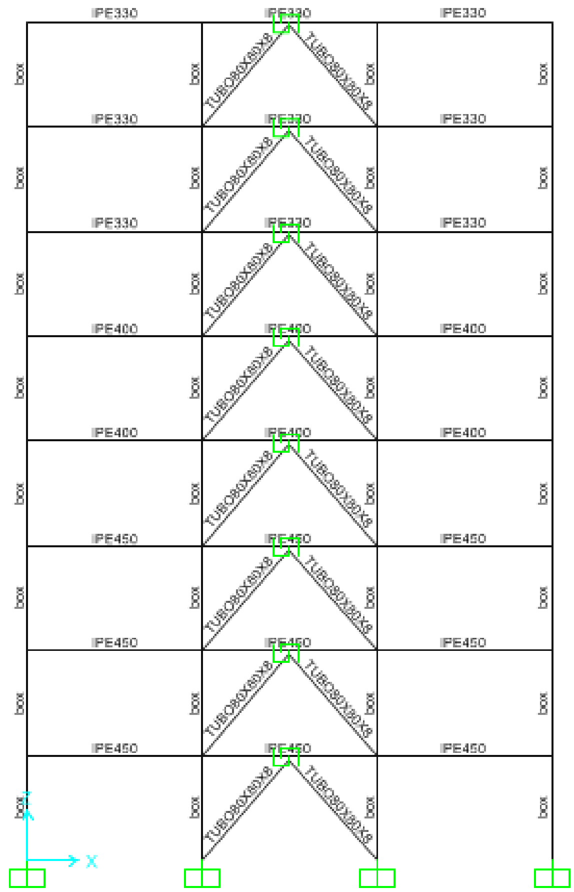

Figure2. 8 story frame with damper

5. Accelerogram Properties

Different accelerograms, in terms of recorded earthquakes in different places, have many differences. Drastic time changes of the ground acceleration with variable frequency are accelerograms. So that it can be infinite combination of amplitude and different wavelength sinusoidal movement. Thus, we can say that the accelerograms has specific frequency content. On the other hand, the maximum amplitude of different accelerograms differ depending on the distance to the relevant earthquake epicenter and its magnitude, this amount is called maximum or peak acceleration in accelerograms.

Accelerograms of the entire duration of the vibrations recorded also have many differences, but also changes in the intensity and duration of the acceleration during acceleration in the records of the last difference is a lot. Thus, the main difference accelerograms of with each other can be outlined as follows:

1- Maximum or Peak acceleration
2- The Frequency content
3- Duration

In this study, four accelerograms Kobe, Tabas, Northridge and Loma Prieta which are soil type III for integral non-linear time history analysis is considered .Accelerograms in both moderate and severe levels were selected for reviewing the behavior of damper and structure.So that Kobe and Tabas have maximum ground acceleration of 0.4g and two other accelerograms, Northridge and Loma Prieta had peak ground acceleration of 0.6g. Figure 3 to 6 shows time history diagram and acceleration spectrum of accelerograms.

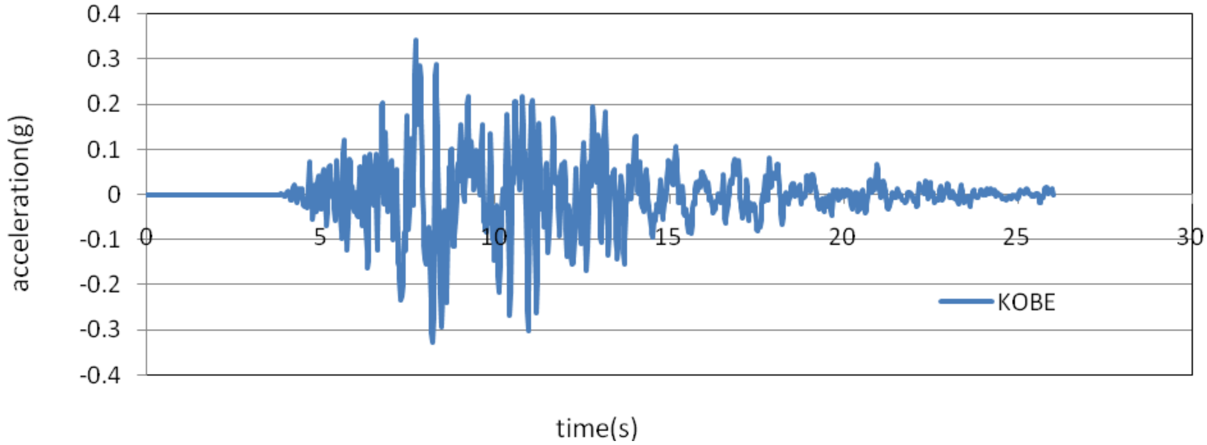

Figure3. Accelerograms of Kobe

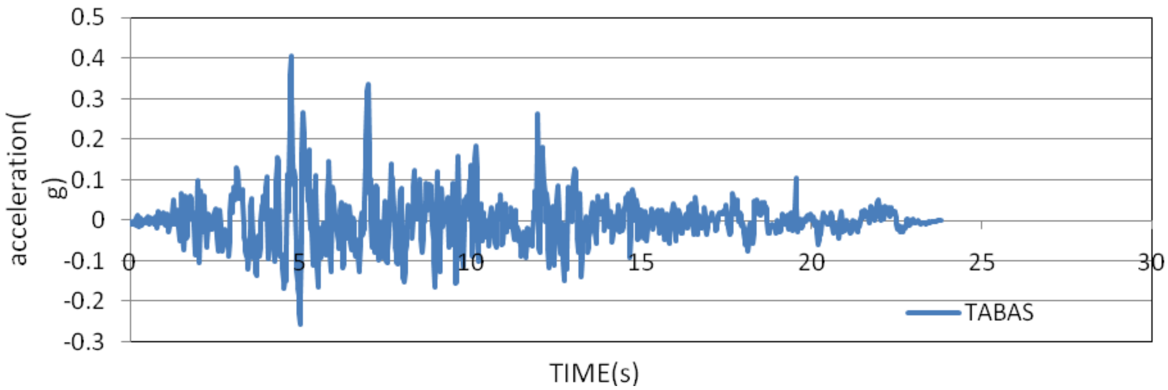

Figure4. Accelerograms of Tabas

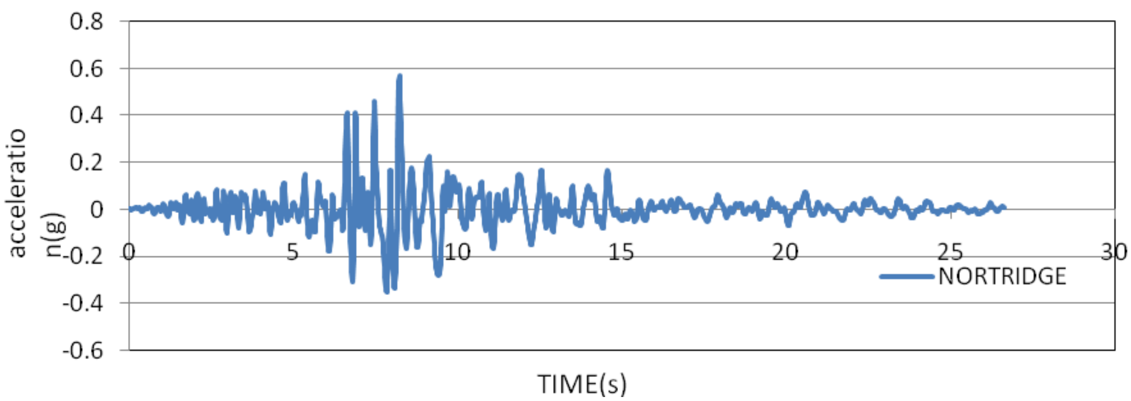

Figure5. Accelerograms of Northridge

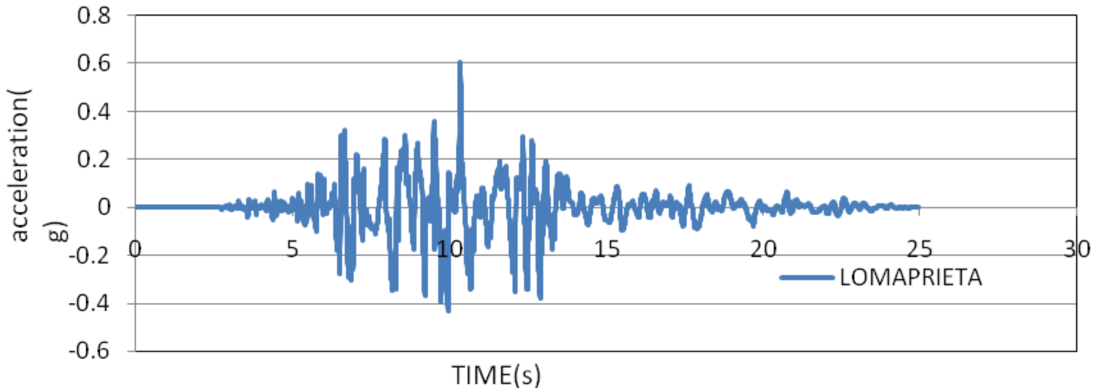

Figure5. Accelerograms of Loma Prieta

6. Base Shear Comparison

Base shear time histories for two case of with and without damper are shown in figure 6 to 17.Comparing the effect of damper in structures, base shear time history in two cases with and without damper has been showed in diagrams simultaneously. The results shows the reduction in base shear by adding dampers in frames, also increasing structure's height cause increasing in period of structure then the less effect of damper in reducing base shear will reveal. The maximum base shear shows in table 4 to 7. According to the results, the most effect of damper in 3 story frame is 53.4% in Tabas earthquake and average reduction of base shear in this frame is 35.77%.Analyses results of 5 and 8 story frames without damper under Northridge and Loma Priea since plastic hinges especially on columns formed thus we can't get the results for base shear but by adding damper plastic hinges will not form on columns.

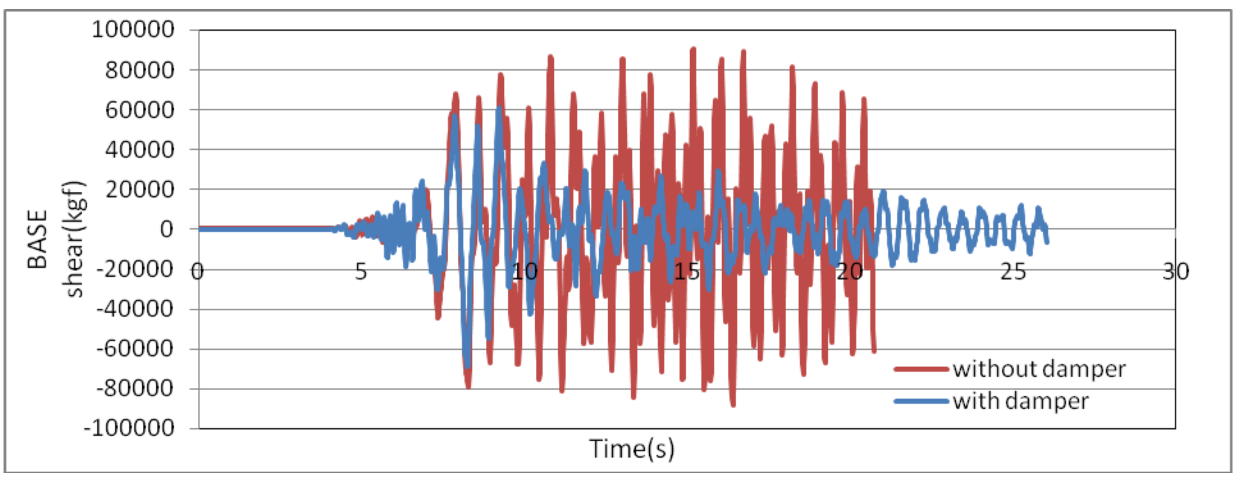

Figure6. Base shear time history of 3story frame under KOBE earthquake

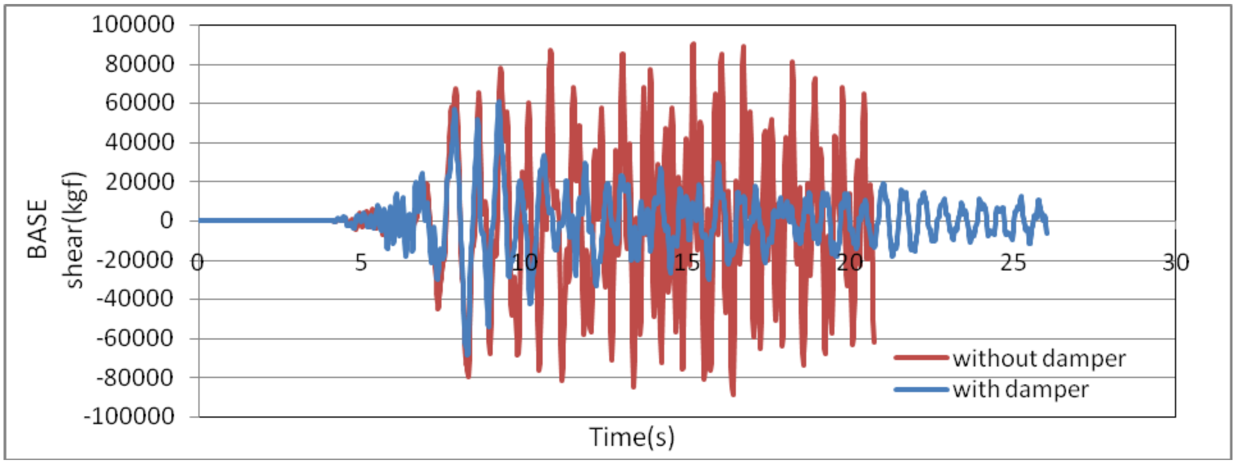

Figure7. Base shear time history of 3story frame under Loma Prieta earthquake

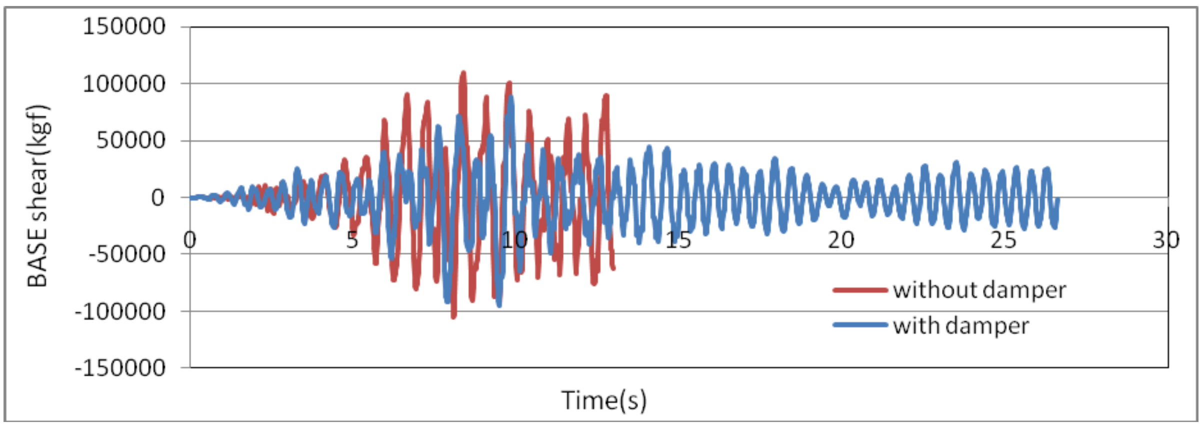

Figure8. Base shear time history of 3story frame under NORTHRIDGE earthquake

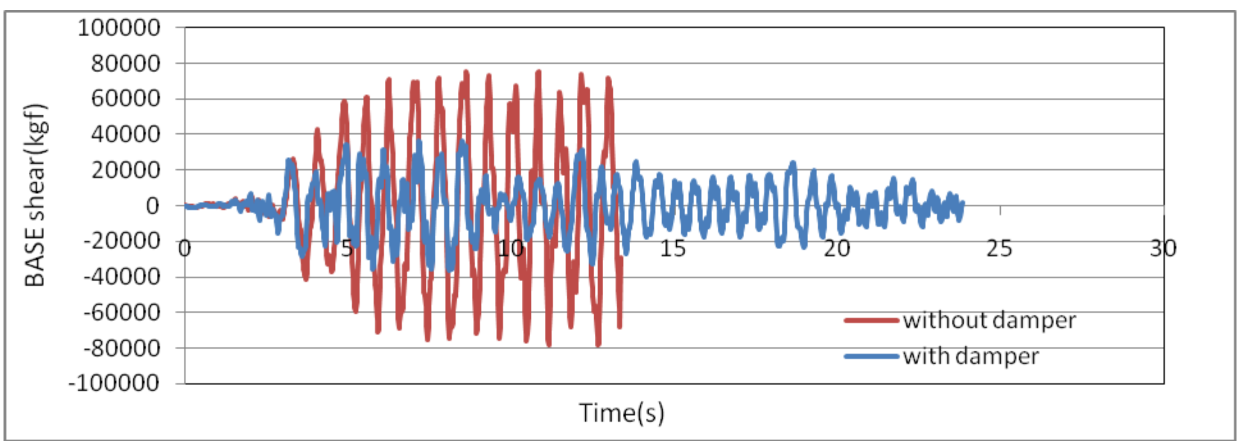

Figure9. Base shear time history of 3story frame under TABAS earthquake

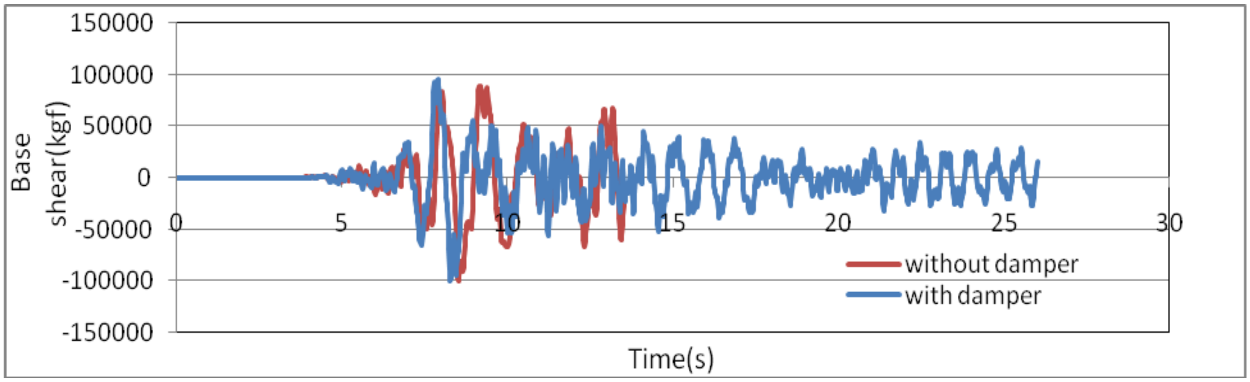

Figure10. Base shear time history of 5story frame under KOBE earthquake

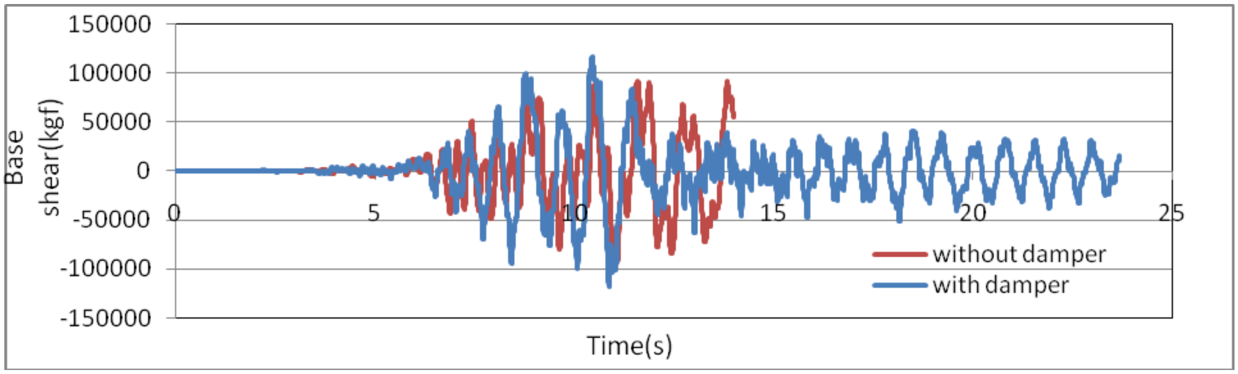

Figure11. Base shear time history of 5story frame under LOMA PRIETA earthquake

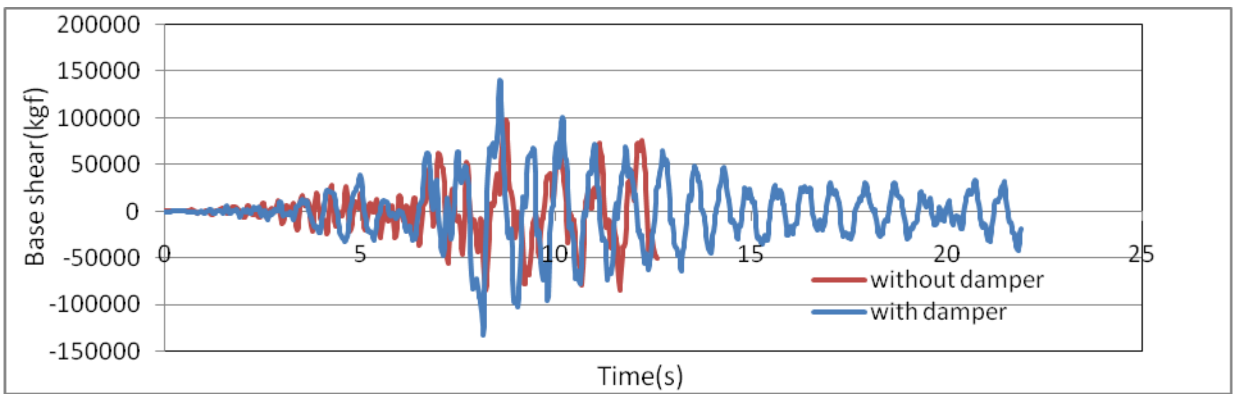

Figure12. Base shear time history of 5story frame under NORTHRIDGE earthquake

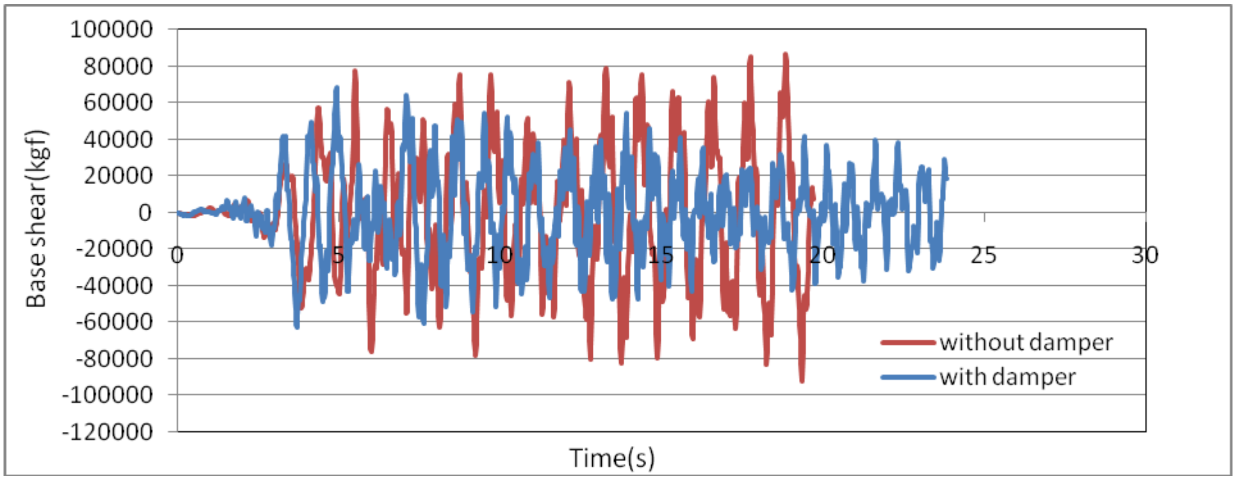

Figure13. Base shear time history of 5story frame under TABAS earthquake

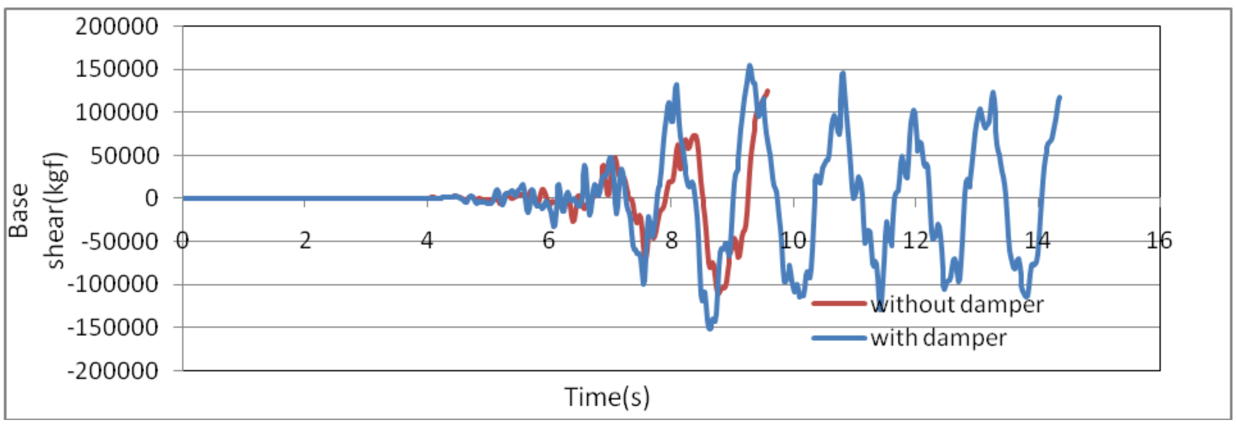

Figure14. Base shear time history of 8story frame under KOBE earthquake

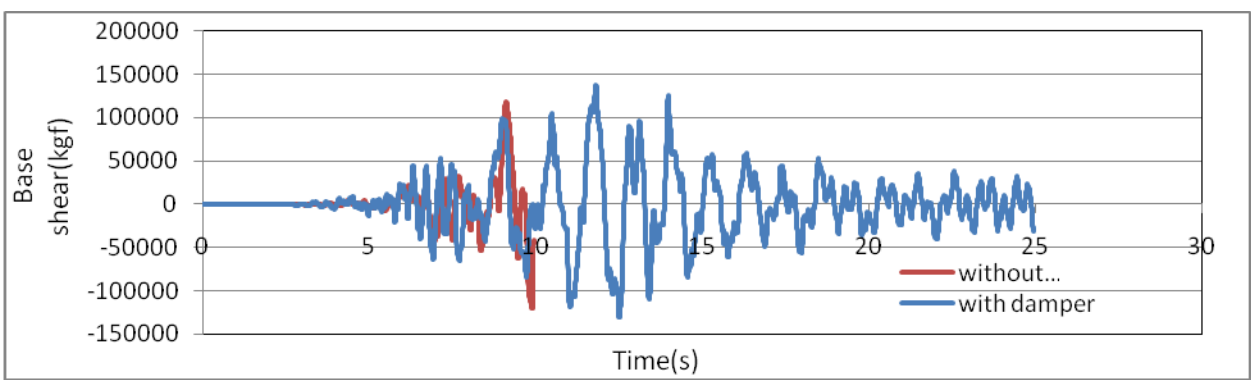

Figure15. Base shear time history of 8story frame under LOMA PRIETA earthquake

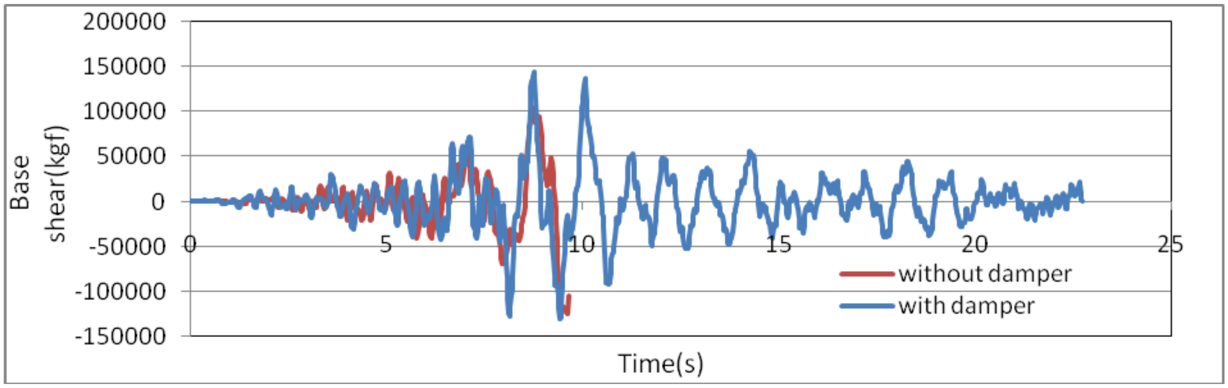

Figure16. Base shear time history of 8story frame under NORTHRIDG earthquake

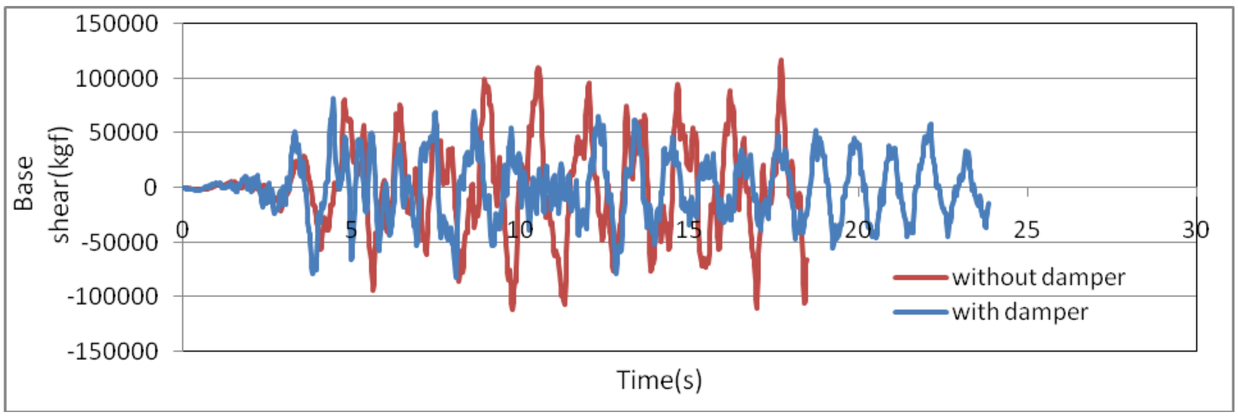

Figure17. Base shear time history of 8story frame under TABAS earthquake

Table4. Maximum Base shear in 3story frame

Reduction (%)	Base Shear with damper(ton)	Base Shear without damper(ton)	Earthquake	
40%	54	90	KOBE	Frame
31.5%	89	130	LOMA PRIETA	Frame
18.2%	87.2	106.4	NORTHRDGE	Frame
53.4%	36.4	78.4	TABAS	Frame

Table5. Maximum Base shear in 5story frame

Reduction (%)	Base Shear with damper(ton)	Base Shear without damper(ton)	Earthquake	
40%	56.8	92.8	KOBE	Frame
-	112.1	89.6	LOMA PRIETA	Frame
-	140.4	-	NORTHRDGE	Frame
27.5%	66.56	91.8	TABAS	Frame

Table6. Maximum Base shear in 8story frame

Reduction (%)	Base Shear with damper(ton)	Base Shear without damper(ton)	Earthquake	
-	146.8	-	KOBE	Frame
-	132.6	-	LOMA PRIETA	Frame
-	139.2	-	NORTHRDGE	Frame
33.5%	77.89	117.2	TABAS	Frame

7. Conclusion

Based on the analysis made on steel moment frames in both cases with and without the damper following results were obtained:

1. Using U-shaped steel yielding damper in steel moment frame reduce base shear in all frames but maximum base shear reduction under TABAS and KOBE earthquake is more than others and damper efficiency reduce by increasing earthquake acceleration.
2. Base shear reduction by using yielding steel damper in 3story frame is more remarkable than 5 and 8story frame.
3. Increasing structure's height reduces the effect of dampers in Base shear.
4. Maximum story shear reduced by adding damper in frames.

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